Isotopically Pure Silicon for Improved Microelectronics
Electronic Materials Program
Lawrence Berkeley National Laboratory
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A collaborative project involving Isonics Corp., the Electrochemical Plant Isotope Separation Facility in Zelenegorsk, Russia (near Krasnoyarsk), and the Electronics Materials Program, Center for Advanced Materials, Materials Sciences Division, Lawrence Berkeley National Laboratory has received Stage One approval by the Initiatives for Proliferation Prevention Program, US Department of Energy. The project will use highly enriched silicon isotopes provided by the Electrochemical Plant to manufacture isotopically pure silane gas, polysilicon rods, and silicon wafers that will be used to (1) perform fundamental experiments in solid-state physics and materials science and (2) manufacture semiconductor devices. The contracts that will govern the operation of the project are currently under negotiation.

With the continued scaling of the microelectronics industry into the deep sub-micron regime, power and heat dissipation are becoming major issues. It is expected that the next generation of microprocessors will dissipate over 100 watts of peak power. This will lead to increased chip operating temperatures and the formation of “hot spots” in some parts of the chip. It has been demonstrated recently that the thermal conductivity of silicon is significantly enhanced by isotopic purification. The enhancement is at least 50-60% at room temperature and 300 - 500% or greater at cryogenic temperatures. Modeling studies have shown that ICs fabricated on ^{28}Si-enriched substrates would operate at significantly lower temperature due to this increased thermal conductivity. Early test wafers with ^{28}Si epitaxial layers have been manufactured by Isonics and are currently being investigated for their improved cooling capability at leading research organizations.

Natural silicon contains in addition to the abundant ^{28}Si (92.23%) two further stable isotopes which are of significant scientific and technical interest. ^{29}Si (4.67%) has an odd net spin nucleus that can serve as a highly specific marker in all electron and nuclear spin-resonance studies and applications. Enrichment to 90% would yield more than an order of magnitude increase in sensitivity. ^{30}Si (3.10%) is the isotope which is used commercially on a large scale to make uniformly doped material via Neutron Transmutation Doping. Enriching silicon crystals with ^{30}Si to 90% would cut the exposure to thermal neutrons and the associated damage by a factor of 30, which is expected to improve the performance of the silicon controlled rectifiers (SCRs) and other electronic devices widely used in the electric power grid which are made with this material.

The Electrochemical Plant is expected to provide 26.5 kg of 99.9% enriched ^{28}Si, 500 g of 90% enriched ^{29}Si, and 500 g of 90% enriched ^{30}Si, all in the form of silicon tetrafluoride, for this project. The project goals are the following.

- Deposit ^{28}Si epitaxial layers on natural Si wafers up to 8” (200 mm) in size for fabrication of IC test circuits and for thermal conductivity testing with the goal of establishing isotopically enriched Si as a viable component of the semiconductor manufacturing process.
- Produce 0.25-1.0” diameter ^{28}Si boules using CVD-deposited poly-^{28}Si as a starting material.
- Generate high-quality P-doped (n-type) Si material via neutron transmutation doping (NTD) of highly ^{30}Si-enriched material.
- Perform fundamental scientific measurements on isotope enriched Si including thermal conductivity measurements in ^{28}Si bulk samples, self- and dopant diffusion and electronic transport studies in isotope superlattice structures, and magnetic resonance studies in ^{29}Si-enriched material.